

Energy Saving of Traditional Buildings Using Building Information Modelling System by Applying Management of Spaces

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Abstract

In early 2018, KSA has announced their 2030 Saudi vision with the aim to move the economy away from oil profits. There are many objectives to achieve this vision; one of them is reducing the facility management cost for all public projects (Saudi gazette 2018). Implementing Building Information Modelling (BIM) in the whole lifecycle of the project can have a significant impact on reducing cost (Eastman, Teicholz et al., 2011). This project is a case study project in AL-Baha University. The project was remodelled using BIM based technology, then the gathered data was input into the Revit file. This has improved the use of spaces and the use of energy in the building among the four colleges. The challenges with the space became serious when the College of Engineering had to share one of the University's buildings with other three colleges and a clinic. There has been an assumption that some members of the management proposed that their current traditional buildings allow no space for the new college to share classrooms and offer spaces to offices for their faculty members. Further issues have arisen which are related to the use of energy and the cost of the usage. Upon the previous argument, the paper proposes that reorganizing spaces within the selected building could reduce more than 30% of the energy, this may save more than 2 million Saudi riyal of the facility management annual budget. In addition, this paper will offer a new understanding to how the facilities in traditional building should be managed to save energy and provide more space for sharing among the universities' buildings

Keywords:

Energy saving, Al-Baha University, Saudi Arabia, Building Information Modelling System, Traditional Buildings.

Introduction

Normally, various types of collected historical data such as drawings, inspections and reports are the main influences of a decision (Motamedi, Hammad et al. 2014). Hence, decisions could be negatively affected by misleads, mistakes and mismanagement, especially when information is not there or has been forgotten or neglected. Moreover, the use of visualization to manage space using BIM based technology has a significant impact on the decision (Olomolaiye, Liyanage et al., 2004; Sabol 2008). In term of saving energy, implementing BIM in the early stages can help to save energy (Wang, Wang et al., 2013).

This article presents the benefits of implementing Building Information Modelling (BIM) to manage spaces in order to reduce energy consumption. This was applied in one of the buildings in the University of Al-Baha. In the past few years, the University was facing issues regarding the use of spaces. These issues became significant when the College of Engineering had to share one of the University's buildings with three other colleges and a clinic. Moreover, there are some parties that assume there is no room for the new college to share classrooms and have offices for their faculty members. Hence, the aim of this paper is to improve the use of classrooms and offices using BIM in this building, and to reduce the cost of energy consumption of this building.

Challenges

The building comprises three levels. The three floor plans of the building were handled in DWG format and the space information is on Excel databases. Based on the drawings, the size of the building is 3953 6m². From the preliminary study, there were various issues that needed to be addressed.

Firstly, information provided from Building Management Department (BMD) in Al-Baha University was not accurate. This was exposed when a random comparison done for the use of spaces between the existing situation with the information provided by BMD. It has been found that some spaces were shown occupied in the provided information which is not true. Also, other spaces were designed and revealed as offices but it has become a storage area.

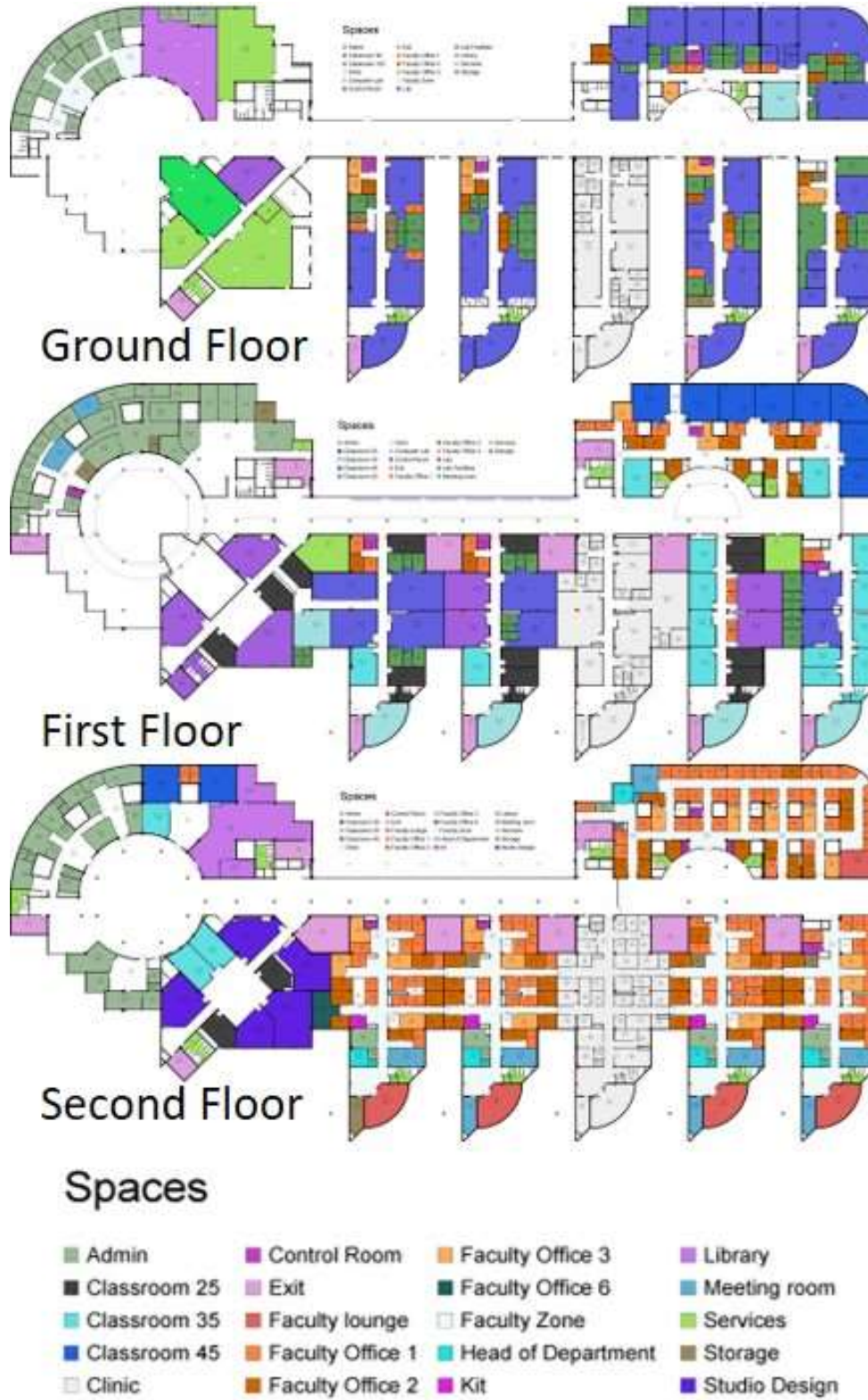


Figure 1: The three plans of the selected building include spaces as in the original design.

Secondly, the unorganized coding used for numbering classrooms, labs and offices has caused several issues to the faculty members and students in finding their classes. In a number of cases, some of the spaces have two different numbers; and in other cases, the number on the sign is not the same number as on the door.

Thirdly, floor plans which are provided by BMD do not array with the existing building. The plans are either missing some areas or uncoordinated. For example, the first floor did not correlate with the grid of the ground floor. These drawings are the only drawings the BMD have.

Method

the aim of this paper is to improve the use of classrooms and offices using BIM in this building, and to reduce the cost of energy consumption of this building. Hence, there are three objectives:

1- Collecting and fixing the current data of the interior spaces for the selected building.

As the Data provided from BMD is not a liable data to use, a site visit and a survey was conducted to gather this information. First, a team of five engineers visited the building and enter every room and space within the building. The task was to find out the status of the spaces i.e. Used, Not Used, Empty, Furniture, No Furniture, Functions, if it's still the same or has changed, and if it was reserved.

Then, as each department has assigned one of their faculty to manage their requirements, a several meetings were organised with the four nominated faculties to validate the information provided from the site visit and to cover their future needs. Finally, after three weeks, an Excel file was delivered containing 27 pages of information.

2- Building a BIM model and adding parameters using BIM technical software.

There are two issues to be covered; incomplete drawings, managing the provided data. Hence, BIM technology such as Revit can be a useful platform to manage these two issues. Because of the lack of the manpower to remodel and enter the provided data, an architectural firm was assigned to remodel and enter the data. The model was handled by them after one month in Revit format; and the cost of that 55250 SR. The project was validated by comparing more than 25% of the spaces with the provided model. The Accuracy was more than 98%.

3- Disputing and managing spaces to reduce energy consumption.

Revit model was used as a platform to manage spaces. Hence, Room Tag was created in Revit to help in linking the excel data with the model. The room tag is a useful tool in Revit which helps to give names and numbers to spaces. It contains parameters which can be filled by space data such as departments, areas, furniture and so on. Moreover, an extra parameter can be added if it is needed.

To make the data an automated data which means when any changes happen in the Excel file it will reflect in Revit, a third application from "ideate" was used to synchronize the data between Excel and Revit. The feeding process had taken more than three weeks. After that, the use of Fields, Filters, Sorting/Grouping, Formatting, and appearance in the Scheduling properties helped to extract information from the model and link it with the plans.

Data Collection and Findings

The Naming System

There are two different systems that have been used for naming spaces. The first system uses three-digit numbers plus the first letter of each level, which is used in banners and on the doors. The BANER sometimes has at least two different names for one classroom. For example, they have classroom S055 as it appears on the door; however, this space is registered in the BANER under the names (S055), (S-055) and (S.055). The reason for having different names for one space is because each college has named the space. In other words, none of these colleges have used the names as it has appeared on the doors. Moreover, some of the colleges find that useful in helping them to register students temporarily in these classrooms until they find a permanent classroom.

Classrooms:



Figure 2: Classrooms, Locations and capacity

The building has 54 classrooms each one has a different student capacity (25, 35, 45, 50, and 100 students). Figure 3 shows how many classrooms the building has based on the classroom capacity. However, the building can accommodate 2100 students at the same time using only the classrooms; this does not include labs.

Figure 2 presents the locations of these classrooms. Most of the classrooms are located on the first floor. The preliminary study shows that six of the classrooms on the second floor have a capacity of 45 or 50 used to teach studio design for architectural students. Moreover, the theatre on the ground floor has no furniture and cannot be used until it is furnished.

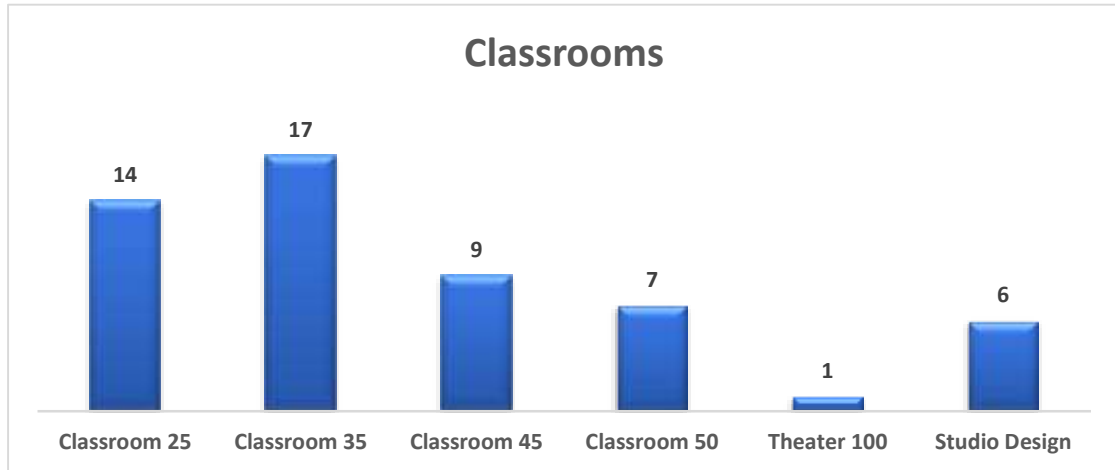


Figure 3: The number of classrooms and the capacity of each one.

Offices

The building has two different types of offices. The first one is for administration and is located in section one (the circle shape). The building has 79 administration offices as shown in table 1. The same table presents the number of the second type of offices, which is for faculty members. There are four different capacities for these offices (one desk, two desks, three desks, and six desks). Figure 4 reveals the number of offices the building has in each level; in total 206 offices of the two types.

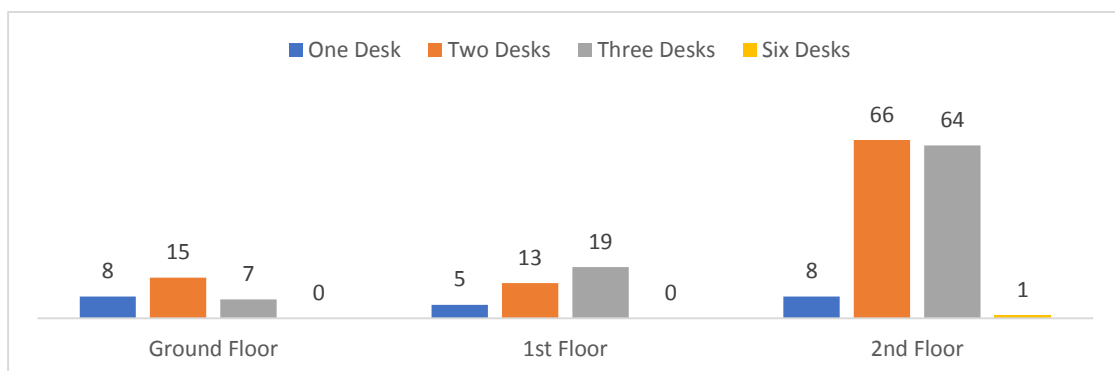


Figure 4: The number of offices in each level.

Furthermore, the 206 offices can have more desks as already mentioned. Table 1 proposes that the building can have 390 desks for faculty members. It shows that most of these desks are located on the second floor—273 desks with more than 70% of the capacity. This is followed by the first floor with 65 desks then the ground floor with 51 desks. Figure 5 presents the location of offices and the capacity of each space.

Table 1: Number of desks in the building

	1 Desk	2 Desks	3 Desks	6 Desks	Admins
Ground Floor	13	32	6	0	19
1st Floor	11	48	6	0	27
2nd Floor	23	198	46	6	33
Total	47	278	58	6	79
	390				



Figure 5: The Location of the offices and the capacity.

Users

The building is used by four colleges; The College of Engineering, The College of Applied Medical Sciences, The College of Pharmacy, and The College of Dentistry; it is also used by a clinic centre. The clinic centre has occupied section 5 of all three levels. This study has not included any spaces from section 5.

There was no official report showing the number of students in each college, therefore, the administration office in Al-Baha University has been asked to provide us with the number. The number of students of the four colleges in 2017 was 2324 students. Figure 6 shows that 49.7% of them were engineering students and 37.4% of them were Applied Medical Sciences students. These two colleges have the largest number of students with 87.4% of the overall number of students. The College of Dentistry has just started, and they have 1.8% of the students.

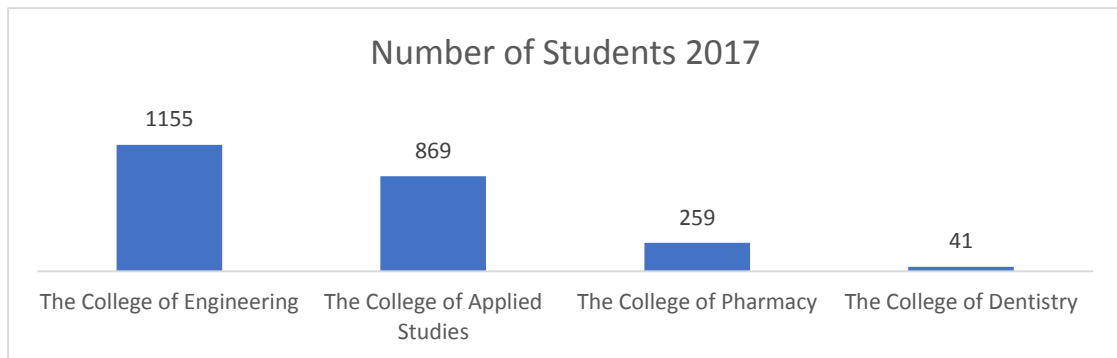


Figure 6: Number of Students in each college in year 2017

In terms of the faculty members, both departments (Faculty member department and IT) have provided us with the number of faculties registered in Al-Baha University in 2017. The University has 183 faculty members. Figure 7 shows that 48% of them were in The College of Engineering and 37.1% of them were in The College of Applied Medical Sciences, then, 11.4% of them were in The College of Pharmacy. Finally, six faculty members in the College of Dentistry.

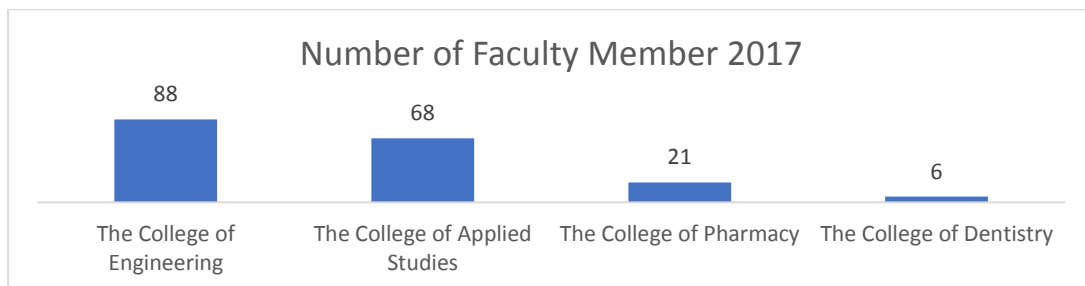


Figure 7: Number of Faculty members in each College for the year 2017

Proposal: Re-naming the spaces in the selected building.

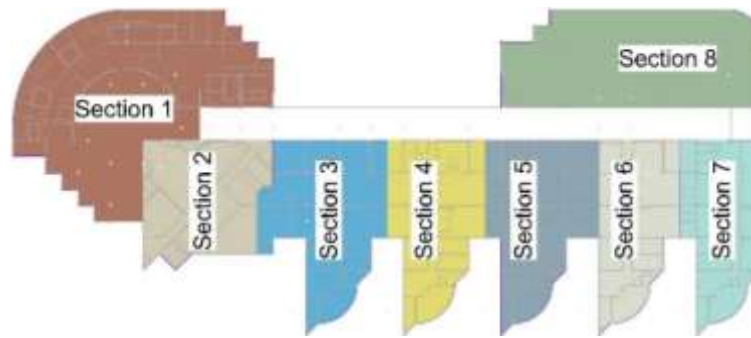


Figure 8: The mapping number of the building's sections

The report suggests renaming the spaces based on three categories: Level, Section, and Number. The building is on three levels and the report proposes to use the first letter for each floor (G – Ground Floor, F – First Floor, S – Second Floor). Then, using the Number of the section, as it has been re-coded, starting from the circle to the last section (See Figure 8). Finally, using two-digit numbers for the numbering of the spaces inside the section. Figure 9 presents the structure of the used code. Some of the sections such as Section One and Eight have more than one entry. Hence, a number will be added before the two-digit numbers to indicate areas within the sections (Figure 9).

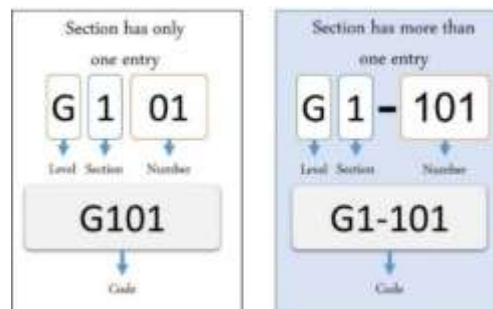


Figure 9: Proposed coding system for this project.

Organising Classrooms:

To divide the classrooms between colleges, the report proposes to use the percentage of students in each college. The total number of students in the building is 2324 students and figure 6 shows that 49.7% of them were Engineering students and 37.4% of them were Applied Medical Sciences students. These two colleges have the biggest number of students with 87.4% of the students. The College of Dentistry has just started and they have 1.8% of the students.

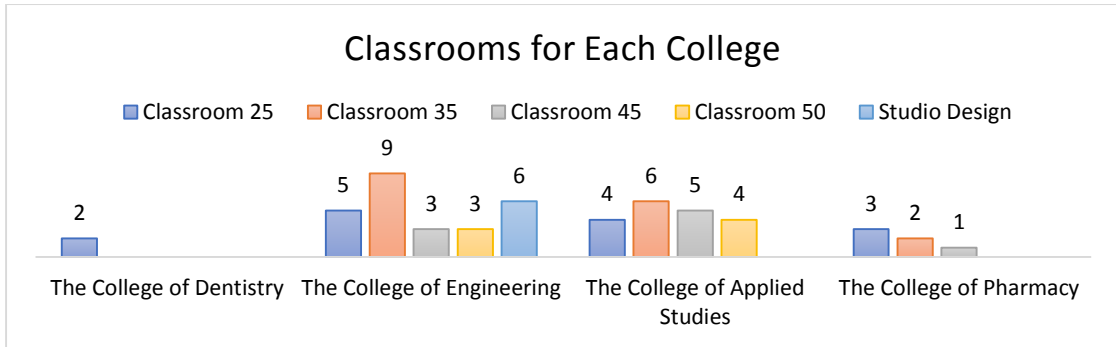


Figure 10: Classrooms for each college and the capacity of each classroom

Using this formula (The total number of classrooms x the percentage of classrooms in Figure 6) will give us the number of classrooms for each college. Figure 10 shows that the number of classrooms for Engineering College is 26 classrooms, Applied Medical Sciences 19 classrooms, Pharmacy 6 classrooms and Dentistry 2 classrooms. These Classrooms are located on the first floor and second floor. Figure 11 shows the location of each classroom and to which college it belongs.

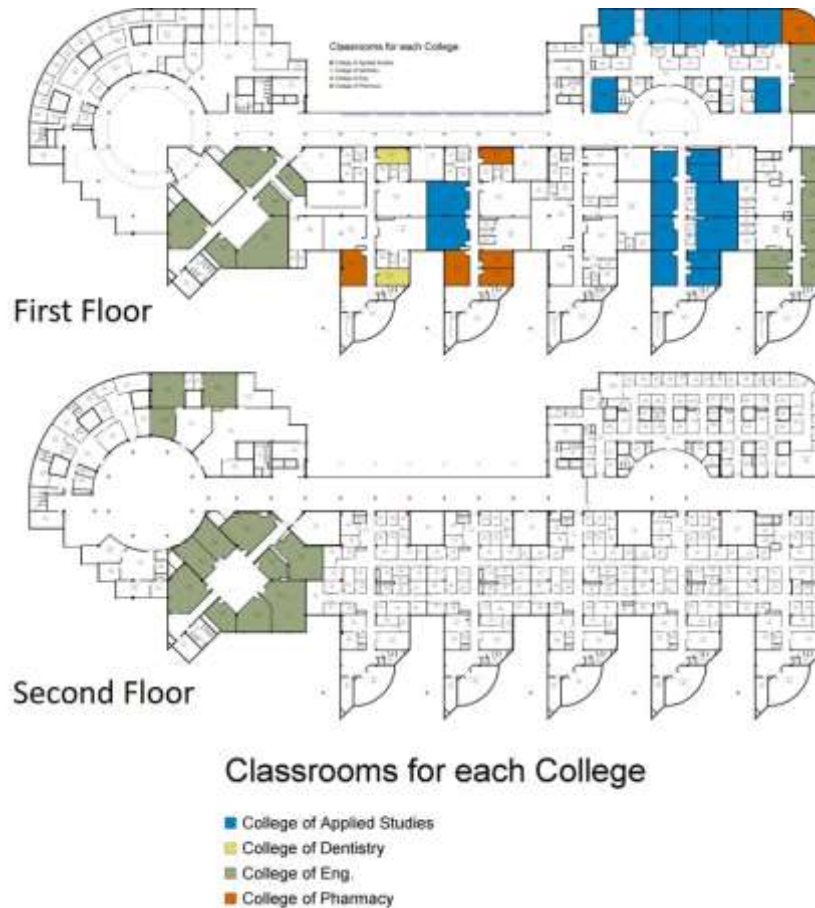


Figure 11: Dividing classrooms between the four colleges

Table 2 presents the area of each classroom and two capacity sizes (Maximum Capacity and Minimum Capacity). The report has used the formula $((Area - (0.2 \times Area)) / 0.9 \text{ m}^2)$ to calculate the maximum capacity of the students, 20% of the space was given as a lecture space, and each student was giving (0.9 m^2) for seating and

moving, for the minimum capacity, the same formula was used but the 20% for lecture space was changed to 30% and the (0.9 m²) was changed to (1.1 m²) for each student.

Table 2: Classrooms for each college and the maximum and minimum capacity

College of Engineering						College of Applied Medical Sciences						College of Dentistry						College of Pharmacy					
No.	Sec.	Area	Capacity		No.	Sec.	Area	Capacity		No.	Sec.	Area	Capacity		No.	Sec.	Area	Capacity					
			Max	Min				Max	Min				Max	Min				Max	Min				
Classroom 25						Classroom 35						Classroom 45											
F201	2	37.77 m ²	34	24	F601	6	33.26 m ²	30	21	F301	3	36.75 m ²	33	23	F401	4	37.03 m ²	33	24				
F203	2	49.73 m ²	44	32	F603	6	41.88 m ²	37	27	F312	3	40.86 m ²	36	26	F411	4	40.66 m ²	36	26				
F205	2	48.64 m ²	43	31	F613	6	39.43 m ²	35	25							F412	4	40.90 m ²	36	26			
S203	2	45.47 m ²	40	29	F614	6	39.97 m ²	36	25														
S208	2	48.51 m ²	43	31																			
F701	7	53.43 m ²	47	34	F602	6	55.89 m ²	50	36							F410	4	63.98 m ²	57	41			
F704	7	56.89 m ²	51	36	F607	6	60.96 m ²	54	39							F311	3	62.53 m ²	56	40			
F706	7	49.63 m ²	44	32	F608	6	58.23 m ²	52	37														
F708	7	55.96 m ²	50	36	F612	6	63.98 m ²	57	41														
F709	7	45.24 m ²	40	29	F8-302	8	64.11 m ²	57	41														
F710	7	44.20 m ²	39	28	F8-101	8	64.87 m ²	58	41														
S207	2	69.84 m ²	62	44																			
S205	2	69.89 m ²	62	44																			
S1-203	1	55.64 m ²	49	35																			
F8-301	8	85.54 m ²	76	54	F8-305	8	85.08 m ²	76	54														
F8-303	8	84.32 m ²	75	54	F8-209	8	91.19 m ²	81	58														
S206	2	77.15 m ²	69	49	F8-208	8	83.78 m ²	74	53														
						F8-112	8	85.83 m ²	76	55													
						F8-110	8	85.88 m ²	76	55													
						Total						69	49										

Classroom 50						Studio Design						Total		300	216
Room	Count	Area (m ²)	Capacity	Area (m ²)	Capacity	Room	Count	Area (m ²)	Capacity	Room	Count				
F202	2	108.34	96			S201	2	108.27	29	S201	2	108.27	29		
F204	2	153.13	136			S202	2	113.79	30	S202	2	113.79	30		
F206	2	104.85	93			S204	2	143.28	38	S204	2	143.28	29		
						S209	2	106.19	28	S209	2	106.19	21		
						SI-201	1	87.41	23	SI-201	1	87.41	17		
						SI-202	1	86.93	23	SI-202	1	86.93	17		
Total						Total						1193	855		
F408	4	99.07	88									1220	874		
F407	4	106.21	94									171	129		
F609	6	103.55	92									300	216		
F604	6	108.85	97											Building Capacity	

Finally, the last formula was used to calculate the capacity of Studio Designed Classrooms. The maximum capacity formula is $(Area - (0.2 \times Area)) / 3 m^2$, each student has $3m^2$. In the minimum formula $(Area - (0.3 \times Area)) / 4 m^2$, the area needed for students has changed to $4m^2$. All formulas were implemented within Revit using Room Tag and Schedules. Hence, the maximum capacity for the building is 2953 students and the minimum capacity is 2123 students. Figure 11 presents the distribution of classrooms between colleges.

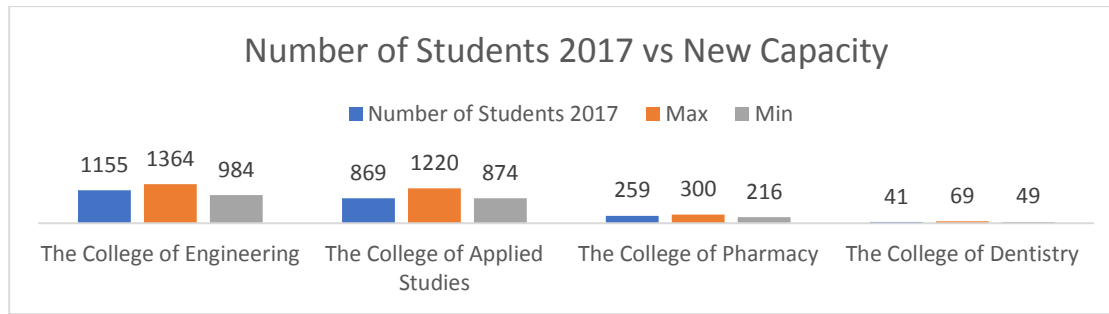


Figure 12: Comparison between number of students in the four colleges and the new capacity of classrooms for each college.

Based on the schedules for lectures for the three colleges (Engineering, Applied Medical Sciences and Pharmacy), around one-third of the total number of students are studying at the same time. The 41 students in The College of Dentistry are the first and the second group that have entered the program. The lecture schedule for the college shows that more than 75% of students are studying at the same time. However, Figure 12 shows that all colleges have more than what they need in terms of classroom capacity.

Organising Offices for Faculty Members

Table 2: Capacity of offices

Offices by Floor	Max Capacity (Small Desk)				Mid Capacity				Min Capacity			
	1 Office	2 Offices	3 Offices	6 Offices	1 Office	2 Offices	3 Offices	6 Offices	1 Office	2 Offices	3 Offices	6 Offices
Ground Floor	8	30	21	0	13	32	6	0	23	10	6	0
1st Floor	5	26	57	0	11	48	6	0	18	34	6	0
2nd Floor	8	132	192	9	23	198	46	7	74	100	38	6
Total	21	188	270	9	47	278	58	7	115	144	50	6
	488				390				315			
Administration				79 Offices								

Table 3 shows that there are three types of capacity (Maximum, Medium and Minimum). Three different formulas were used to calculate the number of desks in the space. First, is the maximum capacity, which is any space less than 10m² and will have only one desk. In this case, table 3 shows that the building has 21 spaces.

Then the spaces that are more than 10m² and less than 14m² will have two desks. This will give each faculty member a space between 5m² to 6.9m². The spaces that are more than 14m² and less than 28m² will host three desks. This will give between 4.67m² to 9.3m² for each

faculty member. Finally, there is one space with an area of 49m^2 , this space can contain 9 desks as shown in table 3; and an area 5.44m^2 for each faculty member. With this solution, 488 desks for faculty members have been provided.

Second, is the medium capacity, which is any space less than 11m^2 and will have only one desk. Moreover, spaces more than 11m^2 and less than 20m^2 will be used by two faculty members. This will give each faculty member an area between 5.5m^2 to 10m^2 . In addition, spaces that are more than 20m^2 and less than 28m^2 will contain three desks; each faculty member will have between 5m^2 to 9.3m^2 . Finally, the 49m^2 will have 7 members, 7m^2 for each faculty member. In this case, 390 desks have been provided to faculty members.

Third, is the minimum capacity, which is in case the space is less than 14m^2 then one faculty member will be using it. If the space is between 14m^2 and 21m^2 , then the space will have two desks. Each faculty member will have an area between 7m^2 to 10.5m^2 . The area between 21m^2 and 28m^2 will hold three desks, giving an area between 7m^2 to 9.3m^2 for each faculty member. Finally, 6 faculty members will be in an area of 49m^2 . The use of minimum capacity formula has provided us with 315 offices for faculty members.

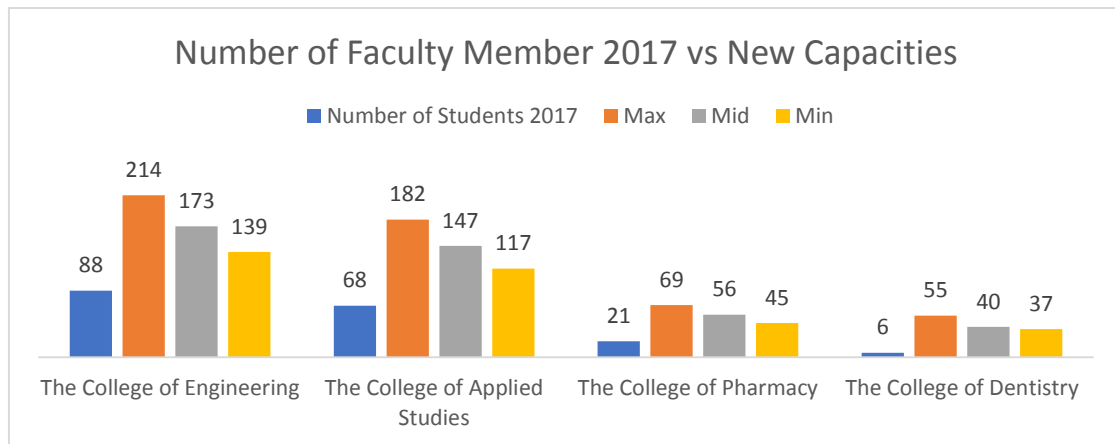


Figure 13: Number of faculty members in 2017 and the new spaces for them

Most of colleges have got more spaces than what they need. Figure 13 shows that the minimum capacity solution has given more spaces for faculty members in each college. The College of Engineering has got 139 offices for 88 faculty members. That means they have got more than 155% of spaces. The College of Applied Medical Sciences has got more than 172% of spaces, 117 offices for 68 faculty members. The other two colleges have got more than double of what they need.

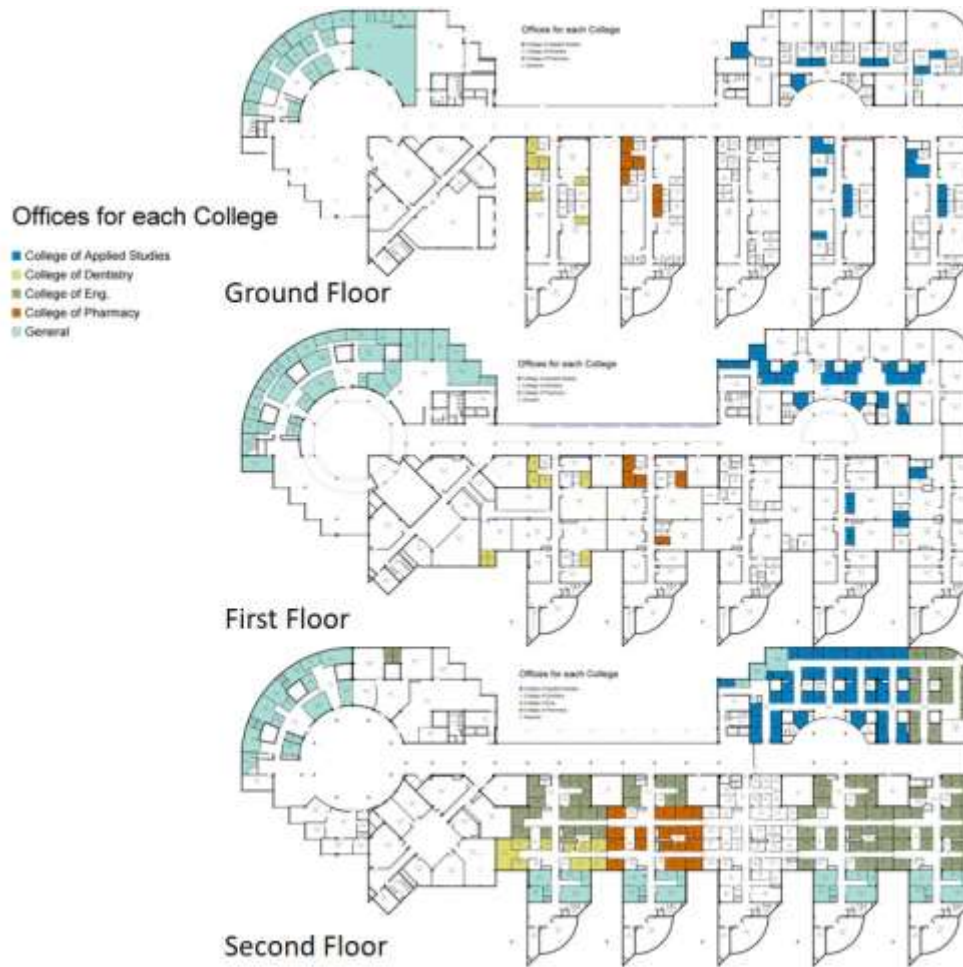


Figure 14: Offices for each college

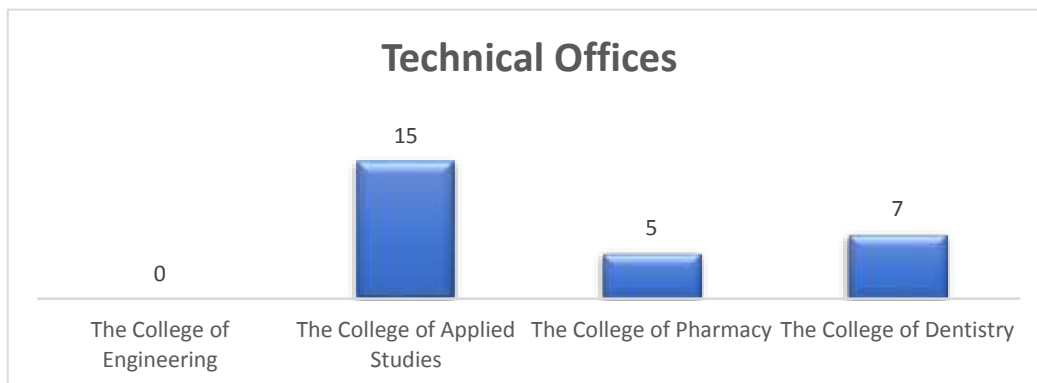


Figure 15: Number of Technical offices

In some college cases two capacities (Maximum Capacity and Medium Capacity) have got more than three time the area they need. Figure 14 presents the locations for each college's offices. Table 4 presents in detail the offices which have been given to each college. However, there are some offices named Technical Office and these offices are located within a lab. Figure 15 shows that The College of Applied Medical Sciences has the highest number of technical offices. They have got 15 technical offices with a minimum capacity of 15 faculty members. This is followed by The College of Dentistry with 7 technical offices and The College of Pharmacy with 5 technical offices.

Table 4: Offices for each college

College of Applied Medical Sciences														
	Number	Name	Area	Max Capacity (Small Desk)			Mid Capacity			Min Capacity				
				1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs		
Ground Floor	Section 6	G605.1	Technical Office	11.67 m ²		2			2		1			
		G604.1	Technical Office	9.67 m ²	1			1		1				
		G601.1	Technical Office	11.67 m ²		2			2		1			
		G603.1	Technical Office	10.21 m ²		2		1		1				
		G602	Office	23.65 m ²			3			3			3	
	Total		5		1	6	3	2	4	3	4	0	3	
	Section 7	G703	Office	11.03 m ²		2			2		1			
		G705.1	Technical Office	11.67 m ²		2			2		1			
		G707.1	Technical Office	11.67 m ²		2			2		1			
		G704	Office	27.26 m ²			3			3			3	
	Total		4		0	6	3	0	6	3	3	0	3	
	Section 8	G8-301.3	Technical Office	9.24 m ²	1			1			1			
		G8-204.4	Technical Office	8.58 m ²	1			1			1			
		G203.4	Office	9.25 m ²	1			1			1			
		G8-202.4	Technical Office	9.13 m ²	1			1			1			
		G8-303.3	Technical Office	10.70 m ²		2		1			1			
		G8-304.2	Technical Office	10.34 m ²		2		1			1			
		G8-101.2	Technical Office	11.64 m ²		2			2		1			
		G8-102.1	Technical Office	10.40 m ²		2		1			1			
	G8-201	Office	17.10 m ²			3		2			2			
	Total		9		4	8	3	7	4	0	8	2	0	
	Total		18		5	20	9	9	14	6	15	2	6	
	First Floor	Section 6	F605	Office	7.62 m ²	1			1			1		
			F606	Office	7.62 m ²	1			1			1		
			F610	Office	6.66 m ²	1			1			1		
			F611	Office	6.66 m ²	1			1			1		
		Total		4		4	0	0	4	0	0	4	0	0
		Section 7	F705.3	Technical Office	10.32 m ²		2		1			1		
F707.1			Technical Office	10.32 m ²		2		1			1			
F702			Office	14.94 m ²			3		2			2		
Total			3		0	4	3	2	2	0	2	2	0	
Section 8		F8-306	Office	12.61 m ²		2			2		1			
		F8-210	Office	12.73 m ²		2			2		1			
		F8-206	Office	13.49 m ²		2			2		1			
		F8-109	Office	13.69 m ²		2			2		1			
		F8-102	Office	12.53 m ²		2			2		1			
		F8-104	Office	10.28 m ²		2		1			1			
		F8-105	Office	10.58 m ²		2		1			1			
		F8-107	Office	18.02 m ²			3		2			2		
		F8-307	Office	18.00 m ²			3		2			2		
		F8-213	Office	17.23 m ²			3		2			2		
		F8-212	Office	15.26 m ²			3		2			2		
	F8-211	Office	17.00 m ²			3		2			2			

	F8-205	Office	18.02 m ²			3		2			2			
	F8-207	Office	17.10 m ²			3		2			2			
	F8-203	Office	25.94 m ²			3			3			3		
	F8-108	Office	17.10 m ²			3		2			2			
	F8-103	Office	21.60 m ²			3			3			3		
	F8-106	Office	15.26 m ²			3		2			2			
	Total		18		0	14	33	2	28	6	7	18	6	
	Total		25		4	18	36	8	30	6	13	20	6	
Second Floor	Section 8	S8-311	Office	9.18 m ²	1			1			1			
		S8-313	Office	12.32 m ²		2			2			1		
		S8-314	Office	12.64 m ²		2				2		1		
		S8-317	Office	11.22 m ²		2				2		1		
		S8-201	Office	12.58 m ²		2				2		1		
		S8-202	Office	11.56 m ²		2				2		1		
		S8-204	Office	12.19 m ²		2				2		1		
		S8-205	Office	12.32 m ²		2				2		1		
		S8-206	Office	10.22 m ²		2		1				1		
		S8-207	Office	12.58 m ²		2				2		1		
		S8-208	Office	10.22 m ²		2		1				1		
		S8-210	Office	10.20 m ²		2		1				1		
		S8-211	Office	12.19 m ²		2				2		1		
		S8-215	Office	12.58 m ²		2				2		1		
		S8-104	Office	11.90 m ²		2				2		1		
		S8-105	Office	11.72 m ²		2				2		1		
		S8-106	Office	12.58 m ²		2				2		1		
		S8-110	Office	10.58 m ²		2		1				1		
		S8-304	Office	12.58 m ²		2				2		1		
		S8-306	Office	12.19 m ²		2				2		1		
		S8-307	Office	12.29 m ²		2				2		1		
		S8-309	Office	11.90 m ²		2				2		1		
		S8-310	Office	11.32 m ²		2				2		1		
		S8-318	Office	17.10 m ²				3		2				2
		S8-214	Office	20.57 m ²				3			3			2
		S8-216	Office	17.10 m ²				3		2				2
		S8-301	Office	17.81 m ²				3		2				2
		S8-302	Office	14.17 m ²				3		2				2
		S8-303	Office	14.78 m ²				3		2				2
		S8-305	Office	22.40 m ²				3			3			3
		S8-308	Office	15.13 m ²				3		2				2
		S8-312	Office	14.11 m ²				3		2				2
		S8-316	Office	21.47 m ²				3			3			3
S8-209	Office	14.45 m ²				3		2				2		
S8-212	Office	15.52 m ²				3		2				2		
S8-101	Office	15.03 m ²				3		2				2		
S8-102	Office	15.86 m ²				3		2				2		
S8-103	Office	15.28 m ²				3		2				2		
	Total		38		1	44	45	5	60	9	23	26	6	
The Total Number of Faculty Members						182		147			117			

College of Dentistry														
	Number	Name	Area	Max Capacity (Small Desk)			Mid Capacity			Min Capacity				
				1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs		
Ground Floor	Section 3	G306.1	Technical Office	9.63 m ²	1			1			1			
		G301.1	Technical Office	9.86 m ²	1			1			1			
		G308.1	Technical Office	9.86 m ²	1			1			1			
		G305	Office	12.16 m ²		2			2			1		
		G303	Office	14.82 m ²			3		2				2	
		G304	Office	14.87 m ²			3		2				2	
Total		6		3	2	6	3	6	0	4	4	0		
First Floor	Section 3	F305	Office	12.68 m ²		2			2		1			
		F308.1	Technical Office	10.64 m ²		2		1			1			
		F308.2	Technical Office	10.51 m ²		2		1			1			
		F303	Office	14.67 m ²			3		2			2		
		F304	Office	15.07 m ²			3		2			2		
		F306.3	Technical Office	14.17 m ²			3		2			2		
		F309.1	Technical Office	14.30 m ²			3		2			2		
Total		7		0	6	12	2	10	0	3	8	0		
Second Floor	Section 3	S320	Office	8.78 m ²	1			1			1			
		S322	Office	12.69 m ²		2			2		1			
		S326	Office	10.54 m ²		2		1			1			
		S323	Office	23.27 m ²			3			3			3	
		S325	Office	17.13 m ²			3		2			2		
		S324	Office	17.59 m ²			3		2			2		
		S329	Office	15.49 m ²			3		2			2		
		S330	Office	17.53 m ²			3		2			2		
		S331	Office	49.12 m ²			9			7			6	
Total		9		0	2	24	1	8	10	1	8	9		
The Total Number of Faculty Members				55			40			37				
College of Eng.														
	Number	Name	Area	Max Capacity (Small Desk)			Mid Capacity			Min Capacity				
				1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs		
Second Floor	Sec1	S1-201.1	Office	10.71 m ²		2		1			1			
		S1-202.1	Office	10.74 m ²		2		1			1			
	Total		2		0	4	0	2	0	0	2	0	0	
	Section 3	S302	Office	10.78 m ²		2		1			1			
		S304	Office	11.44 m ²		2			2		1			
S306		Office	13.51 m ²		2			2		1				

	S303	Office	11.34 m ²		2			2		1			
	S311	Office	13.46 m ²		2			2		1			
	S313	Office	11.98 m ²		2			2		1			
	S314	Office	10.83 m ²		2		1			1			
	S317	Office	10.54 m ²		2		1			1			
	S316	Office	11.82 m ²		2			2		1			
	S305	Office	14.01 m ²			3		2			2		
	S308	Office	27.50 m ²			3			3			3	
	S309	Office	14.52 m ²			3		2			2		
	S310	Office	22.88 m ²			3			3			3	
	S312	Office	18.59 m ²			3		2			2		
	S315	Office	17.59 m ²			3		2			2		
	S318	Office	25.72 m ²			3			3			3	
	S319	Office	18.29 m ²			3		2			2		
	Total		17		0	18	24	3	22	9	9	10	9
Section 4	S402	Office	10.80 m ²		2			1			1		
	S404	Office	11.44 m ²		2				2		1		
	S406	Office	13.86 m ²		2				2		1		
	S403	Office	11.34 m ²		2				2		1		
	S405	Office	14.10 m ²				3		2			2	
	S408	Office	27.79 m ²				3				3		3
	S409	Office	14.82 m ²				3		2			2	
Total			7		0	8	9	1	10	3	4	4	3
Section 6	S620	Office	8.77 m ²	1				1			1		
	S602	Office	10.78 m ²		2			1			1		
	S604	Office	11.44 m ²		2				2		1		
	S606	Office	13.51 m ²		2				2		1		
	S603	Office	11.34 m ²		2				2		1		
	S607	Office	11.81 m ²		2				2		1		
	S611	Office	13.85 m ²		2				2		1		
	S613	Office	11.98 m ²		2				2		1		
	S614	Office	10.83 m ²		2			1			1		
	S617	Office	11.90 m ²		2				2		1		
	S622	Office	12.69 m ²		2				2		1		
	S626	Office	11.90 m ²		2				2		1		
	S605	Office	14.01 m ²				3		2			2	
	S608	Office	18.43 m ²				3		2			2	
	S609	Office	14.82 m ²				3		2			2	
	S610	Office	22.88 m ²				3			3			3
	S612	Office	18.59 m ²				3		2			2	
	S615	Office	17.59 m ²				3		2			2	
	S618	Office	18.23 m ²				3		2			2	
	S619	Office	17.02 m ²				3		2			2	
S623	Office	23.18 m ²				3			3			3	
S625	Office	17.13 m ²				3		2			2		
S624	Office	17.59 m ²				3		2			2		
S630	Office	17.02 m ²				3		2			2		
S629	Office	16.41 m ²				3		2			2		
Total			25		1	22	39	3	40	6	12	22	6
Section 7	S719	Office	8.17 m ²	1				1			1		
	S702	Office	10.81 m ²		2			1			1		
	S704	Office	11.44 m ²		2				2		1		

S706	Office	13.87 m ²	2			2		1				
S705	Office	13.85 m ²	2			2		1				
S703	Office	11.07 m ²	2			2		1				
S714	Office	11.90 m ²	2			2		1				
S721	Office	10.92 m ²	2		1			1				
S720	Office	11.34 m ²	2			2		1				
S718	Office	11.16 m ²	2			2		1				
S723	Office	11.90 m ²	2			2		1				
S726	Office	16.56 m ²		3		2				2		
S727	Office	17.33 m ²		3		2				2		
S707	Office	14.93 m ²		3		2				2		
S709	Office	22.75 m ²		3			3				3	
S711	Office	14.35 m ²		3		2				2		
S712	Office	14.52 m ²		3		2				2		
S710	Office	22.58 m ²		3			3				3	
S715	Office	18.25 m ²		3		2				2		
S716	Office	17.33 m ²		3		2				2		
S722	Office	14.10 m ²		3		2				2		
Total		21	1	20	30	3	32	6	11	16	6	
Section 8	S8-405	Office	9.14 m ²	1		1			1			
	S8-409	Office	8.86 m ²	1		1			1			
	S8-414	Office	8.84 m ²	1		1			1			
	S8-415	Office	8.52 m ²	1		1			1			
	S8-403	Office	11.39 m ²		2		2		1			
	S8-406	Office	12.71 m ²		2		2		1			
	S8-407	Office	10.20 m ²		2	1			1			
	S8-411	Office	11.67 m ²		2		2		1			
	S8-412	Office	13.46 m ²		2		2		1			
	S8-416	Office	12.19 m ²		2		2		1			
	S8-417	Office	12.64 m ²		2		2		1			
	S8-420	Office	12.58 m ²		2		2		1			
	S8-402	Office	17.59 m ²		3		2				2	
	S8-401	Office	21.03 m ²		3			3			3	
	S8-408	Office	18.02 m ²		3		2				2	
	S8-410	Office	18.20 m ²		3		2				2	
	S8-413	Office	14.88 m ²		3		2				2	
S8-419	Office	20.57 m ²		3			3			2		
Total		18	4	16	18	5	22	6	12	10	3	
Total		9	6	88	120	17	126	30	50	62	27	
The Total Number of Faculty Members			214			173			139			
College of Pharmacy												
	Number	Name	Area	Max Capacity (Small Desk)			Mid Capacity			Min Capacity		
				1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs	1 Off	2 Offs	3 Offs
٥	٤	G405	Office	12.16 m ²		2		2		1		

		G401.4	Technical Office	11.67 m ²		2			2		1			
		G406.2	Technical Office	10.45 m ²		2		1	2		1			
		G407.4	Technical Office	11.67 m ²		2			2		1			
		G403	Office	14.82 m ²			3		2			2		
		G404	Office	15.09 m ²			3		2			2		
		Total		9		0	8	6	1	12	0	4	4	0
First Floor	Section 4	F409.3	Technical Office	9.01 m ²		1			1			1		
		F405	Office	12.34 m ²			2			2		1		
		F403	Office	14.67 m ²				3		2			2	
		F404	Office	15.02 m ²				3		2			2	
		F406.3	Technical Office	14.29 m ²				3		2			2	
		Total		9		1	2	9	1	8	0	2	6	0
Second Floor	Section 4	S420	Office	8.78 m ²		1			1			1		
		S411	Office	13.46 m ²			2			2		1		
		S413	Office	11.98 m ²			2			2		1		
		S414	Office	10.83 m ²			2		1			1		
		S417	Office	11.90 m ²			2			2		1		
		S422	Office	12.69 m ²			2			2		1		
		S426	Office	11.90 m ²			2			2		1		
		S410	Office	22.88 m ²				3			3			3
		S412	Office	18.68 m ²				3		2			2	
		S415	Office	17.59 m ²				3		2			2	
		S418	Office	18.23 m ²				3		2			2	
		S419	Office	17.02 m ²				3		2			2	
		S423	Office	23.27 m ²				3			3			3
		S425	Office	17.13 m ²				3		2			2	
		S424	Office	17.59 m ²				3		2			2	
S429	Office	16.41 m ²				3		2			2			
S430	Office	17.02 m ²				3		2			2			
		Total		9		1	12	30	2	26	6	7	16	6
The Total Number of Faculty Members						69			56			45		

Recommendation for Saving Energy

If each college uses all the spaces that are needed in the next five years to maximum capacity, the university can save energy. Figure 16 is a part of a report used to analyse the distribution of lectures in some of classrooms during the day and the week. More than 90% of lectures were located in the morning and at noon. Moreover, less than 8% of lectures were taught on Thursday.

Percentage of occupancy (Week)	Percentage of occupancy (Day)	Percentage of occupancy	Occupation												Space				
			Evening			Afternoon			Noon			Morning			Days	Capacity	New Name	Old Name	
			22-20:50	21-20:50	20-20:50	19-17:50	18-17:50	17-17:50	16-15:50	15-15:50	14-14:50	13-13:50	11-11:50	10-10:50					9-9:50
27.14%	35.71%	0.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%	0.00%	0.00%	0.00%	50	F403	F089
	14.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%			
	35.71%	0.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	75.00%	0.00%	0.00%	0.00%	0.00%			
	21.43%	0.00%	0.00%	0.00%	0.00%	50.00%	0.00%	0.00%	0.00%	0.00%	0.00%	25.00%	0.00%	0.00%	0.00%	0.00%			
	28.57%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%			

Figure 16: Sample of the report used to analyse the distribution of lectures.

It seems that morning and afternoon are the busy times of the day and Thursday is a quiet day. However, figure 17 shows the percentages of classroom use during the week; and Figure 18 shows the percentages of using fake classrooms. The average utilization rate of the classrooms is 21.67%, and for the fake classrooms is 23.88%. That means the four colleges have used classrooms 45.55% of the time. That means less than 6 hours per day.

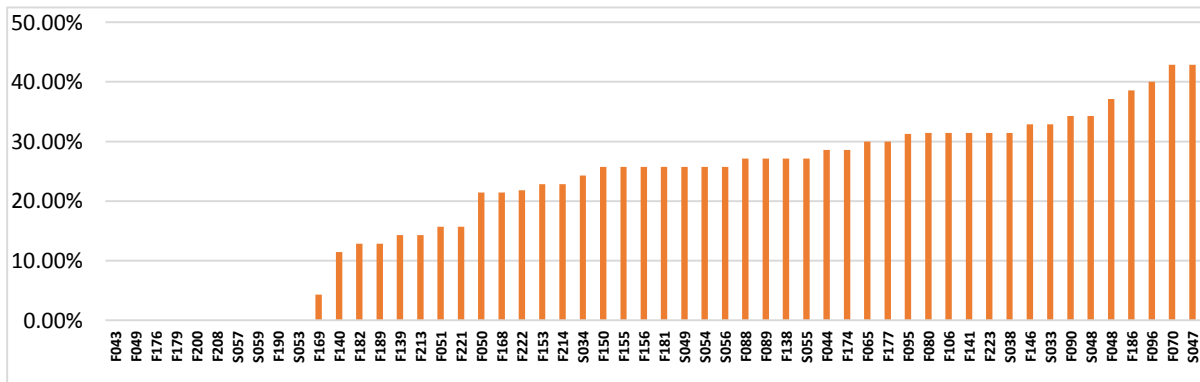


Figure 17: The percentages of classroom use during the week

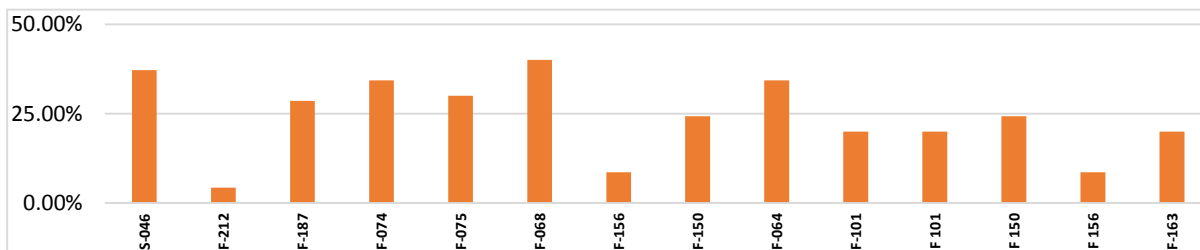


Figure 18: The percentages of using fake classrooms during the week

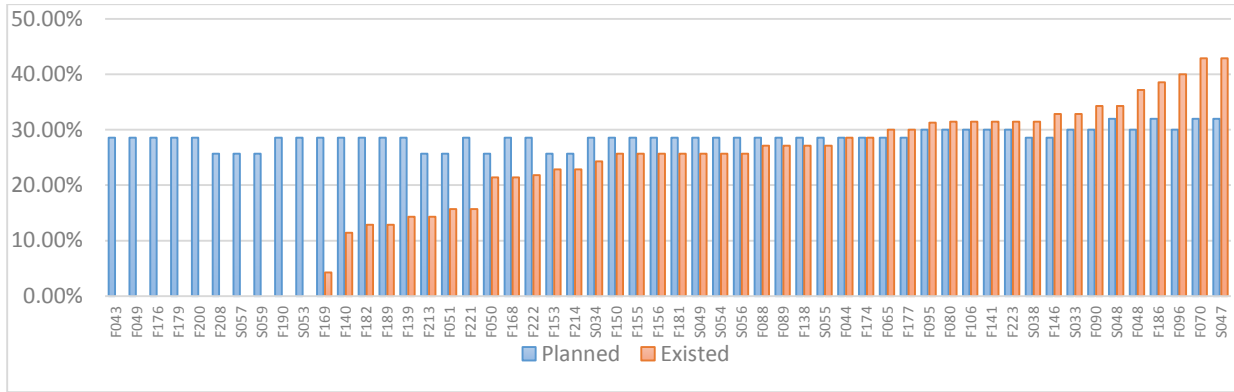


Figure 19: Comparison between the existing classrooms and the proposed plan (Option One)

The morning lectures start at 8 am until 11:50 am which are four sessions. The afternoon sessions start from 12:00 pm until 16:50 pm; also four sessions. Although, the teaching times normally start at 8 am until 16:00 pm, there are some lectures that were given after 16:50 pm. These lectures make up 8.07% of the time. The morning session got an overall of 36.36% of the time during the week. Hence, by distrusting classrooms among colleges and covering their needs, it has been concluded that all lectures can be hosted during the morning time (see figure 19). This will help to save energy as the rest of the day will be unoccupied; this was option one.

Option two is presented in figure 20, it proposes that the classrooms in First floor, in three wings will be closed during the semester. the number of these classroom is 22 classrooms which is 40% of the classrooms in the building. The 60% of the other classrooms have to be occupied until the 16:00 pm. This option can help to reduce the energy consumption when the mention sections are closed.

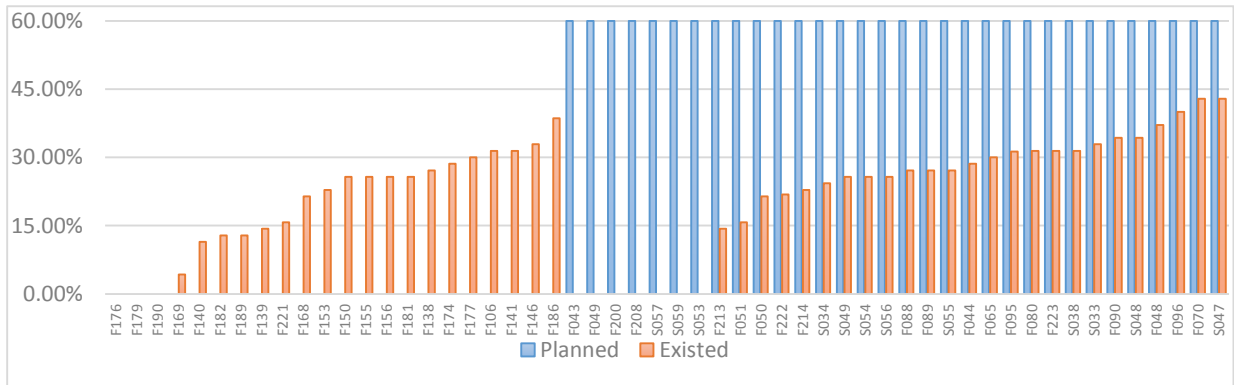


Figure 20: Comparison between the existing classrooms and the proposed plan (Option Two)

• **Future Needs:**

Based on the nominated faculties from the four colleges, after five years more than 20% of the total number of the students is expected to increase as they will be enrolled in their programmes. Moreover, some of them have some concerns that the number of graduate students will drop 10%. Option one in figure 21 shows that most of the classrooms can be occupied until 14:00 pm which is still advantage for University to save the power during the rest of the day.

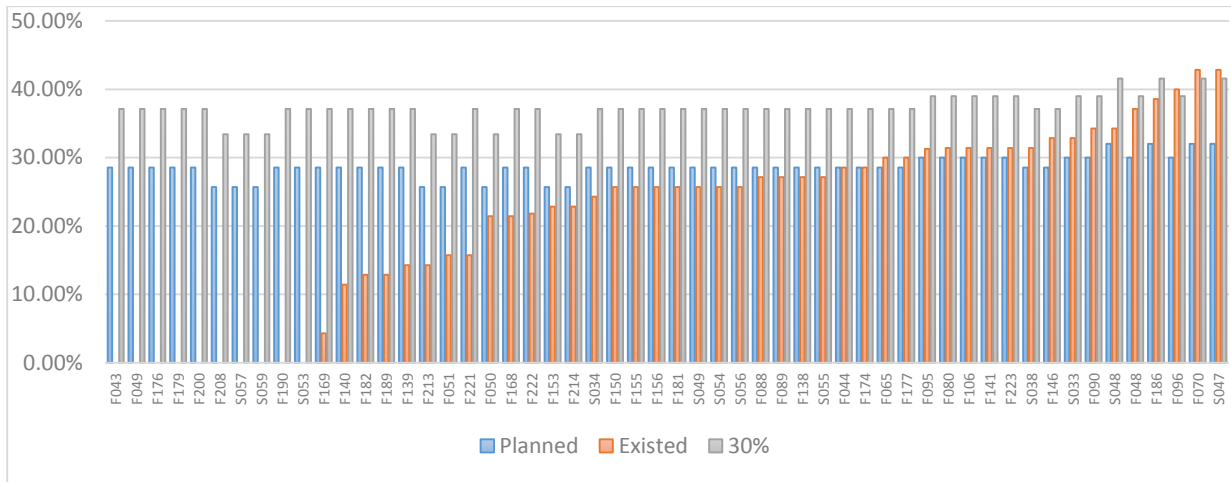


Figure 21: Comparison between the existing classrooms, the proposed plan and the future 30% (Option One)

On the other hand, the second option proposes that one of the three closed sections that was proposed previously, will open to cover their needs. Hence, the number of closed classrooms is 15 classes.

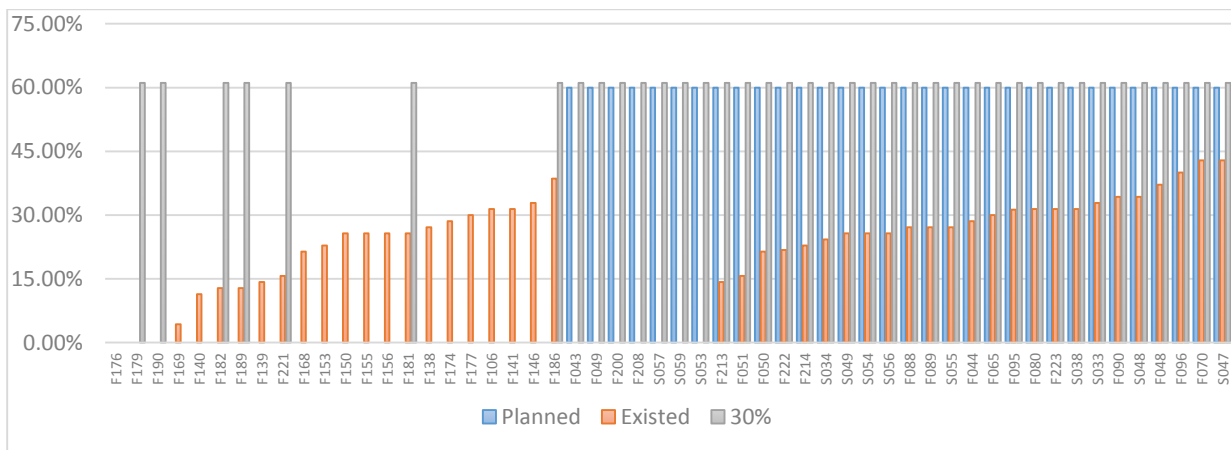


Figure 22: Comparison between the existing classrooms, the proposed plan and the future 30% (Option Two)

Conclusion

Using BIM based technology has helped to link an automated model with this data. This link enhances the use of space in the building effectively. The paper concludes that implementing BIM in an existing building to merely manage space can significantly reduce the use of energy. In this case study, the University can save energy up to 65% by either apply the first option or the second one. In the first option, all classrooms are occupied for half of the day only; until 12:00 pm; which give them a choice to close the classes for the rest of the day. On the other hand, option two gives them a choice to close some wings for the rest of the semester. Although, the cost of this study is around 55000SR, the owner can save more than three Million SR as the annual expenses for electricity is around 5 Million SR based on BMD.

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